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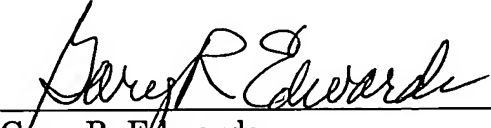
**SUBMISSION OF SUBSTITUTE SPECIFICATION**

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July 17, 2006

Sir:

Attached are a Substitute Specification and a marked-up copy of the original specification. I certify that said substitute specification contains no new matter and includes the changes indicated in the marked-up copy of the original specification.

  
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Method and Apparatus for producing a hollow section or shell section

BACKGROUND AND SUMMARY OF THE INVENTION

**[0001]** This application claims the priority of German patent document 10 2004 002 267.4, filed January 16, 2004 (PCT International Application No. PCT/EP2004/014267, filed December 15, 2004), the disclosure of which is expressly incorporated by reference herein.

**[0002]** The invention relates to a method and apparatus for producing a hollow section or shell section.

**[0003]** During hydroforming, contoured hollow sections or half shells are produced from surfaces placed one on top of the other ("sheet blank expansion"), or from tubular blanks, by inserting and sealing the sheets or tubular blanks into a die of an HF tool. A fluid is then applied to the sheets or tubular blanks at a corresponding high pressure, in order to form the latter. Hydroforming is used in the production of frame structure components in the automobile sector, for example for the production of body members.

**[0004]** Such frame structure components need to be connected to other surrounding components. In the conventional production of frame structure components, flanges are generally provided at the ends of the components for connection to the surrounding components in order to permit an appropriate

connection to other components, for example by spot welding. For this purpose, components produced by hydroforming are subsequently subjected to further processing steps, such as cutting or bending for example, for which the hollow section or shell profile must be deflected to the desired length in a separate processing step.

**[0005]** While flat cut contours can in this case still be produced by a simple saw cut running transversely to the axial/longitudinal direction of the hollow section or shell section, cut contours running in three-dimensional space for flange surfaces (which are increasingly occurring in particular in the use of frame structure components in vehicle body construction,) have to be produced in an elaborate manner, by laser or plasma cutting. The flanges are then produced by subsequent bending of the material pieces or extensions still remaining on the workpiece.

**[0006]** It goes without saying that such subsequent processing steps require additional processing machines. In addition, the components have to be transported from the HF device to the subsequent processing stations. These circumstances lead to an increased expenditure of time and to considerably higher production costs.

**[0007]** To perform cutting in an HF tool, European patent document EP 100 43 81 A2 discloses a device comprising die plates, which are integrated in the tool and cutting edges, and a plurality of support plungers which bear axially against said die plates. Both the die plates and the plungers are provided at the

periphery at one end of the hollow section blank to be formed. The end of the blank projects from the HF tool. During expansion of the blank by high pressure fluid, the periphery of the blank butts against the cutting edges. The support plungers are pushed toward the hollow section blank via drive wedges by hydraulic or pneumatic cylinders until they come to bear against one another. In this manner, they form a small peripheral gap with the hollow section blank, so that, by continuing the expansion, the end of the blank is pre-cut at the cutting edges. The drive wedge is then retracted, so that the plungers are lowered in the bottom tool part. In this way, the peripheral gap in the bottom region of the blank is markedly increased and the blank shaped into the desired hollow section is completely cut off there at the end at the cutting edges. However, the plungers in the top tool part remain in their previous position due to gravitational force, while the drive wedges move outward. On account of the expanding hollow section, the plungers are pushed apart, after which the cutting edges are exposed.

**[0008]** Since the cutting edges are exposed much earlier than in the top tool part due to the lowering of the plungers in the bottom tool part, the trimming in the bottom tool part is effected earlier than in the top tool part. During the trimming, however, a pressure drop occurs in the hollow section, so that only the bottom peripheral region of the hollow section is severed neatly. In the top region, either no complete parting is effected or the parting contour of the hollow section is at least undefined there, so that a rework operation is

inevitable in order to completely sever the initially cut top region or to transfer the parting contour into the desired mold profile.

**[0009]** This complicates the entire process of producing the hollow section and is affected by production tolerances on account of the required additional transfer to a suitable parting or rework device. In addition, the cut contour is in this case determined over the periphery of the section by the shape of the cutting edges. Since the die plates bear symmetrically against the periphery of the HF component in the present case, this device is suitable only for hollow sections having a rotationally symmetrical or rectangular cross section. However, the tongues formed on the end of the hollow section by the trimming can be used as fastening flanges after a resetting operation.

**[0010]** One object of the present invention is to provide a relatively simple method and apparatus for hydroforming HF components having joining flanges connected to them in one piece.

**[0011]** This and other objects and advantages are achieved by the method and apparatus according to the invention, in which notches are formed by means of notching punches that are displaceable in the radial direction relative to the hollow section or shell section, so that defined separation points are created between the lateral notch margins running in the component longitudinal direction. These separation points are parted by a parting device separate from the punches, forming the extension section and a cut-off component which exposes the component to be produced. After removal of the hollow or shell

section thus produced, the extension sections are bent over outside the HF tool to form a flange section in each case, by a bending device.

**[0012]** This constitutes a simple production method, in which the acting tools form the extension sections in a reliable and exactly reproducible manner. By means of the notching punches, the arrangement and shape of the notches is relatively flexible. Thus the notching punches need not necessarily form a rectangular shape, rather, they can produce triangular or polygonal shapes, which, depending on the requirements, can have virtually any desired contour. Therefore very diverse shapes of the component ends of a hollow section or shell section can already be produced in the HF tool in a highly precise manner.

**[0013]** The notching punches may themselves have cutting edges at their end face, which act upon the hollow or shell section in a cutting manner and punch a notch slug out of the latter from outside into the interior of the hollow section or shell section.

**[0014]** At the same time, however, for producing the notches it is also possible for the notching punches to give way relatively quickly in their passage, and in the process expose a cutting edge (formed on the cavity of the die of the HF tool) at the orifice opening of the passage. In this way, driven by the internal high pressure, on account of the resulting contact pressure of the hollow or shell section on the cavity of the die at the location of the notch that is to be produced, a hole slug is cut out into the passage of the notching punches via the cutting edge of the cavity. The hole slug becoming jammed in the passage can be pressed

out of the passages later in a simple manner, for example by advancing the notching punches, after removal of the hollow section or shell section from the tool. A collecting device must be placed in the region of the passages, which prevents the hole slugs from falling into the empty cavity.

**[0015]** Care must always be taken when forming the notches to ensure that the notching punches provide a sufficient seal, so as to prevent a pressure drop inside the hollow section or shell section, which would ruin a desired formation of the notches or extension sections to be formed. It may be emphasized at this point that three-dimensionally re-created and symmetrical cuts on the hollow section or shell section can be easily produced by a specific shape of the cutting edge of the end face of the notching punches or of the cavity, as a result of which the forming of the extension sections becomes especially variable.

**[0016]** In a preferred embodiment of the invention, the apparatus according to the invention also has a cutting device which is separate from the punches and is intended for initially cutting the component along the terminating edge of the extension section to be produced. The cutting device is arranged inside the HF tool and directly adjoins the notching punches in the peripheral direction of the tool cavity. The parting device, which severs the component along the initial cut, is arranged outside the HF tool.

**[0017]** According to another feature of the invention, a predetermined separation point is achieved by the initial cutting of the component, and if need be, is extremely thin-walled so that it can be parted with the least possible effort outside the hydroforming tool by means of a parting device of simple construction. This may be done in such a way that the hollow or shell section is simply knocked off at the thin point produced. Furthermore, the hollow or shell section with the component to be parted can be removed in one piece as an entity from the HF tool, which considerably reduces the handling and transport cost.

**[0018]** The cutting device in this respect may be designed, for example, in a simple manner as a knife-like cutting edge which plunges into the material of the hollow or shell and in the process severs the hollow section or shell section except for a thin web. The cutting device may in this case be arranged in the same axial position as the notching punches, since, even when the hollow section or shell section is acted upon from outside to inside by means of the notching punches, the cutting device in this case in no way gets into the clip-in region of the notching punches.

**[0019]** A further embodiment of the apparatus according to the invention, also includes a cutting device separate from the notching punches, for cutting through the component along the terminating edge of the extension section to be produced except for a thin, axial web adjoining the notch margins. The cutting device is arranged inside the HF tool and adjoins the notching punches at a slight distance apart in the peripheral direction of the tool cavity. The parting

device severing the component at the location of the web is arranged outside the HF tool.

**[0020]** Due to the formation of a thin axial web that is produced by the method according to the invention, the parting operation performed by the parting device arranged outside the HF tool is facilitated because the material is to be severed to a reduced extent.

**[0021]** Because the cutting device now largely cuts through the hollow or shell, if it acts upon the hollow or shell in the same direction as the notching punches, the cutting device would come into contact with the latter in such a way that the notching punches and the cutting device impair one another in an undesirable manner. Care must therefore be taken in the case of an axially identical arrangement of cutting device and notching punches, that the displacement movement of the notching punches runs in the opposite direction to that of the cutting device. The hollow or shell is in this case preferably cut from outside to inside by means of the cutting device, whereas the notches, via the notching punches giving way in the passages, are produced from inside to outside at the cutting edge of the cavity. In this variant, too, the component thus trimmed can also be removed as an entity in one piece from the HF tool.

**[0022]** In the case where the cutting device consists of punches which have a knife-like end face, the punches are likewise displaceable, like the notching

punches, although in separate passages and to this end can be capable of being driven mechanically, pneumatically or hydraulically.

**[0023]** In another preferred embodiment of the invention, the parting device for cutting through the component along the terminating edge of the extension section to be produced is arranged inside the HF tool, so that it directly adjoins the notching punches in the peripheral direction of the tool cavity but is axially offset from said notching punches in their engagement region. This arrangement has the advantage that the parting device is accommodated inside the HF tool in a space-saving manner and replaces the cutting device, the cost in terms of equipment and process, without losing the function of the complete parting of the component to be cut off.

**[0024]** Furthermore, this embodiment of the invention advantageously allows the hollow section or shell section to be acted upon in the same direction by the notching punches and the parting device. Since the notching and the cutting-through of the component is as far as possible to be effected at the same time in order to avoid the risk of a pressure drop, the fact that the hollow section or shell section is acted upon in the same direction due to such an arrangement of the parting device offers a considerable advantage for the process reliability of the production of the component with simultaneously reduced control outlay for the device.

[0025] The cutting-through of the component effected according to an embodiment of the invention by means of the parting device inside the HF tool along the terminating edge of the extension section to be produced can be carried out in a plurality of variants. In a special configuration of the apparatus according to the invention, the parting device may be formed by cutting punches, by which the component can be parted linearly in a simple manner along the abovementioned terminating edge during or after the notching. Alternatively, however, it is possible for the parting device to likewise consist of notching punches which sever the component simultaneously and produce notches in the cut-off component, forming a notching pattern with regard to a center cutting line in the form of alternating notches. This has the special advantage that the cut-off component itself can still be used and need not be disposed of as scrap. The cut-off component in this case likewise has extension sections which can be bent over and serve as fastening flanges. This parting of the component, to be cut off, from the hollow section or shell section need not necessarily be effected at the end, but rather may also be carried out centrally for example, in which case, if need be, identical parts with flanges can be produced from a single workpiece blank in a very economical manner in terms of the process.

[0026] Apart from that, it is also possible for the alternating notches to be formed in such a way that a thin axial web remains, which must be parted outside the HF tool by means of the parting device. The notches on the component to be cut off are in this case made by the cutting device, which must be of appropriate design.

[0027] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0028] Figure 1 is a cutaway longitudinal sectional view of a hollow section in a hydroforming tool with axially offset notching punches according to the invention;

[0029] Figure 2 is a cross-sectional illustration along section line II-II in Figure 1, during a notching operation;

[0030] Figure 3 is a cross sectional illustration along section line III-III in Figure 1, during the notching operation;

[0031] Figure 4 is a lateral plan view of a segment of the hollow section notched according to the invention by the device in Figures 1 to 3, and having an axial web connecting the diagonally opposite extension sections;

[0032] Figure 5 shows the hollow section in Figure 4 after the severing and exposing of the extension sections, in a lateral plan view; and

[0033] Figure 6 shows, in a cross-sectional illustration, the hollow section in Figure 5 along section line VI-VI.

## DETAILED DESCRIPTION OF THE DRAWINGS

[0034] The device 1 for producing a hollow or shell 2 in Figure 1 contains a hydroforming tool 3, which has a top die 4 and a bottom die 5, the cavities 6 of which define a mold space 7, into which the hollow section 2 is inserted. For the shaping expansion of the hollow section 2, an axial plunger 8 closes the respective orifice opening 9 of an end 10 of the hollow section 2. In the present representative embodiment, the end 10 is shaped like a bottle neck by the internal high pressure, exerted in the hollow section interior 11, of a pressure fluid introduced via the axial plunger 8. On that side of the bottle neck 12 which is remote from the axial plunger, passages 13 are formed in the top die 4 and the bottom die 5, and notching punches 14 which are radially displaceable with respect to the hollow section 2 are arranged in the passages 13. The notching punches 14 are arranged offset from one another in the peripheral direction.

[0035] Adjoining the side 35 of the notching punches 14 which faces the bottle neck 12 is a cutting device that is also designed as notching punches 15 and is guided in a displaceable manner in passages 16 of the HF tool 3 radially relative to the hollow section 2. While the notching punches 14 (as seen in Figure 2) are arranged merely in the corner region 17 of the hollow section 2 of box-shaped design and can act upon the latter only at this location, the notching

punches 15 of the cutting device are arranged in the region of the longitudinal sides 18 of the hollow section 2 in the HF tool 3 and can only act upon said longitudinal sides 18 (figure 3). The notching punches 15 are therefore arranged offset from the notching punches 14 in such a way that the notching punches 15 almost completely cover the arrangement gaps 19 between the notching punches 14 and the notching punches 14 almost completely cover the arrangement gaps 20 between the notching punches 15. Furthermore, the notching punches 15 are thus arranged outside the engagement region of the notching punches 14 in such a way as to be axially offset from the latter. However, as stated, they adjoin one another almost directly in the peripheral direction of the tool cavity 6.

[0036] After shaping has been performed by internal high pressure, the notching punches 14 are retracted suddenly in their passages 13 in this embodiment. In the process, a cutting edge 21 extending along the passage margins and formed on the cavities 6 of the top die 4 and the bottom die 5 is exposed, the hollow section 2 being trimmed along said cutting edge 21, with notches 22 and in each case an associated notch slug 23 being formed. In this case, the notch slug 23 butts against the end face 24 of the respective notching punch 14 and, driven by the internal high pressure still applied, is pressed together with said notching punch 14 into the passage 13. After that or even at the same time, the notching punches 15 are displaced according to figure 3 toward the hollow section 2, punch notch slugs 25 out of the latter and plunge together with the notch slugs 25 into the hollow section interior 11.

[0037] After the notching has been completed, the notching punches 15 are retracted into their passages 16. In principle, it is also possible that the mode of displacement of the notching punches 15 and 14 for forming the notches can be kinematically reversed. The pressure fluid is then relieved and directed out of the hollow section interior 11. After that the HF tool 3 is opened and the hollow section 2 thus trimmed at the periphery at an axial distance from its end 10 is removed from the HF tool 3.

[0038] The hollow section 2, which can be seen in Figure 4, accordingly has notches 22 and 26 which are axially offset from one another and are spaced apart separately in the peripheral direction. Extension sections 27 and 28 remain between the notches 22 and between the notches 26, the extension sections 27 being connected to the extension sections 28 at the notch margins 29 by a thin, axial web 30. On account of its notches 26, the extension section 27 is therefore almost completely cut through at its terminating edge 31 and the extension section 28 is almost completely cut through at its terminating edge 32 by the notches 22.

[0039] In order to divide the hollow section 2 produced in such a way into two parts 33 and 34 in the region of the notches 22 and 26, the hollow section 2 is severed at the location of the webs 30 outside the HF tool 3 by means of a parting device (not explained in any more detail here), which results in a component 33 as can be seen Figures 5 and 6. The extension sections 27, the terminating edges 31 of which are now completely exposed, are bent over by means of a bending

device (likewise not explained in any more detail here) to form a flange section of the hollow section or shell section. The webs 30 may possibly also already break off when being cut through on account of their stretching in the case of a very small wall thickness, so that a separate parting device outside the hydroforming tool can be dispensed with.

**[0040]** The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.